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In-vehicle Technologies, Advanced Driver Assistance Systems and Driver Distraction: Research challenges

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Abstract

Technological advances in motor vehicles have provided drivers with both increased safety and access to information. Drivers can receive phone calls, be provided with navigational and real time traffic information, and be notified about impending collisions and excessive speed. However, these devices also increase the potential for a driver to be distracted, as each device demands a certain level of the driver's attention in order to provide a benefit. A growing body of research is currently assessing driver distraction levels in order to determine what impact such devices have on road safety. However, very little research has focused specifically on the combined impact of multiple in-vehicle devices within the driving situation. As a result, this paper provides a review of current research that has examined the effect of in-vehicle technologies and Advanced Driving Assistance Systems (ADAS) on driver distraction, as well as identifying possible directions for future research that will incorporate human distraction within the design.

1. Introduction

Driver distraction is a contributing factor in a significant number of traffic crashes with some estimates suggesting it is a contributing factor in more than 20% of motor vehicle crashes (Harbluk, Noy, & Eizenman, 2002; Transport Canada, 2003; Utter, 2001). Currently, a number of technologies are available that can operate within a vehicle. These devices offer drivers assistance to either avoid hazardous situations, or provide information to make travelling easier. As these systems become more prolific in the market, the potential number of devices that can operate within a vehicle at any one moment increases. This number is increased further with the addition of wireless communication devices that can also operate within a vehicle. With so many devices and systems operating in a vehicle at one time, the potential for driver distraction is enormous, as several devices may compete for the driver's attention. Consequently, a device could interrupt a driver during a manoeuvre or divert a driver's attention at a crucial moment. Therefore, the driving situation, or more accurately, the driving context, must be taken into account by these devices in order to minimise the negative effects they have on road safety. This paper provides a review of current research that has examined the effect of in-vehicle technologies and Advanced Driving Assistance Systems (ADAS) on driver distraction, as well as identifying possible directions for future research in this area that incorporates human distraction within the design.

2. In -Vehicle Technologies and Driver Distraction

Driver distraction involves the diversion of a driver's attention away from the driving task. Potential distractors have been described in different ways in the literature. Kanianthra (2004) puts forward two broad categories of in-vehicle technologies as potential causes of distraction; external stimuli and other passengers. The "external stimuli" category only partially covers the distractors mentioned by Stutts, Reinfurt, Staplin, and Rodgman (2001) who also highlight the impact of moving objects inside the vehicle in addition to eating, drinking or smoking when driving. Distraction can also be defined in terms of the driver's modes of processing input and acting. For example, Young, Regan, and Hammer (2003) suggest that driver distraction can be caused via visual, cognitive, auditory and biomechanical means. A more satisfactory approach is to define driver distraction as any activity that causes the driver to focus their attention on non-relevant driving stimuli and not on the primary task of driving (Ranney, Mazzae, Garrott, & Goodman, 2000). These activities can be internal (cognitive or affective) or external (physical) to the driver, or can be located inside or outside of the vehicle. Taking up Young et al's (2003) description, anything occurring around the driver that requires the driver to utilise visual, auditory, cognitive or motor (biomechanical) functions, increases the potential for distraction.

The impact of technology on driver performance is a popular research area. As a result of this research it is evident that in-vehicle technologies and ADAS can distract the driver. Laberge-Nadeau, Maag, Bellavance et al (2003) estimate that crash risk is increased by 38% if a mobile phone is used while driving, and Redelmeier & Tibshirani (1997) state that there is a similar safety risk whether a driver is using a hands-free or physically manipulated mobile phone, increasing the crash risk by some four times. Other systems which interact with the driver include those that provide real-time traffic information, collision or lane departure warning systems, and route guidance systems. Janssen, Kaptein, and Claessens (1999) tested the reaction times of drivers when using different real-time traffic information systems compared with just the radio playing continuously. The authors conclude that "driving with this type of in-vehicle device is not necessarily to be considered less safe than driving with conventional congestion information" (p. 6). However, the study shows that regardless of the means of presenting congestion information to the driver, it still results in increased unsafe behavioural judgments, according to an experienced driving instructor. When drivers were provided with the same congestion information during a car following and braking task there was a marked increase in unsafe judgements when receiving information, compared with just listening to a radio.

Collision or lane departure warning systems represent a different category, as they are specifically designed to interrupt the driver and provide a warning. As these systems are intended to draw attention from other activities, testing their distracting potential is more challenging and this may explain why they have not been tested as distractors. Route guidance systems have also been identified as distractors, with the entry of destination information considered to be the most distracting task associated with the use of these systems (Young et al., 2003).

A common element in these research findings is the use of technologies which make demands on visual attention and require manual data entry. However, speech-based interfaces are currently being used with in-vehicle technologies such as guidance systems, offering a viable alternative to manual destination entry.

3. Speech-based Interfaces

It has been estimated that 90% of information exploited by drivers is visual. It is the most important source of information available to the driver (Wierwille, 1993). Therefore vision is likely to be the principal sensory mode for detecting information that requires the drivers' attention. Tapping into this limited visual resource is potentially dangerous as driving performance declines as visual demand increases (Tsimhoni & Green, 2001). In an effort to reduce the visual and biomechanical distraction associated with in-vehicle technologies, research into speech-based interfaces for in-vehicle technologies and ADAS has been conducted (Lai, Cheng, Green, & Tsimhoni, 2001; Lee, Caven, Haake, & Brown, 2001). These systems enable the driver to input and receive information via spoken word. This allows drivers to continue to look at the road and keep their hands on the steering wheel, whilst receiving directions and important information, or interacting with devices. However, this technology still does not address the problem of cognitive distraction.

Cognitive distraction occurs whenever a driver requires cognitive activity to do anything other than driving. Speech-based interfaces, although freeing the driver from visual and biomechanical distraction, still require cognitive activity in order to be used. Research conducted by Lee, Caven, Haake, and Brown (2001) supports the notion that a speech-based interface can distract drivers. Their results reveal that this form of interaction with devices draws upon cognitive resources required for driving thereby increasing the time it takes to react to a lead vehicle, which is intermittently braking, by 30%.

4 Multiple In-Vehicle Devices

Few studies have been conducted that measure the combined impact of these devices on driver distraction. Although data on distraction is available for many technologies, it is not valid to simply combine these results in order to discover their total impact. Lansdown, Brook-Carter, and Kersloot (2004) investigate the effect of multiple secondary tasks and conclude that simultaneous distractions from two separate tasks result in "significantly greater mental workload on the driver" (p. 102). In-vehicle devices and ADAS are not "aware" of the current driving context, so do not take into account what the driver is currently doing when they provide their information, and do not have the ability to recognise if another device is also trying to interact with the driver. This means that there is a potential for the driver to be concentrating on a crucial manoeuvre when provided with information from not one, but multiple devices.

This is a particular issue when considering warning systems. Lane departure systems will provide an alert if the driver has not indicated before leaving the lane and collision warning systems will provide an alert regardless of whether or not the driver is aware of the situation. If a driver is leaving a lane without indicating, to avoid a collision they do not need to be provided with yet another source of information, let alone from multiple sources. This is also a potential issue if a driver is provided with congestion or navigation information at the moment a collision warning system is triggered. This additional information is provided at the worst possible time, potentially slowing the driver's reaction time as their cognitive resources are used to interpret several simultaneous pieces of information. Context-aware systems could provide a solution to the problem of simultaneous information conflicts. If each device was aware of everything that was happening around it, simultaneous information conflicts could be reduced or removed entirely.

5. Context-Aware Systems

Context-awareness is a concept that has emerged from the pervasive and ubiquitous computing community. Dey (2001) defines context as "any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (p. 5), suggesting that in order for a system to be context-aware it must use "context to provide relevant information and/or services to the user, where relevancy depends on the user's task" (p. 5). In relation to this paper the context would then refer to any information used to characterise the situation of a driver. For example, what the driver sees, the current state of mind and cognitive load on the driver, the current actions of the driver, the environment inside and outside the vehicle, and the current driving situation.

Huang, Trivedi, and Gandi (2003) provide an example of a context-aware system, as one that attempts to alleviate driver distraction caused when using a mobile phone, by presenting contextual information to the remote caller. This enables the remote party to observe the driving context while the conversation is taking place, as though they were a passenger in the car. This technology is envisaged to give the electronic "passenger" the same access to visual cues, allowing them the ability to alter the conversation style, as though they were witnessing the same thing as a passenger. The system provides an estimation of gaze direction, the current workload of the driver and audio visual warnings, utilising cameras to gather visual information about the interior space and the surroundings of the vehicle. This system provides a good example of how contextual information can be used to reduce driver distraction. However, it is designed to give more information to humans and not to devices, and does not attempt to reduce driver distraction by removing simultaneous information conflicts.

While context-aware systems have not been used to address driver distraction there appears to be potential in operationalising the context-awareness concept. In practice a context-aware driving system would need to monitor driver distraction levels by integrating information on the current workload and driver state. A key component of this task is to have information on the distracting potential of in-vehicle devices. Two ways of doing this are to either detect distraction when the devices are actually in use, or use models to predict the effects.

5.1. Distraction Detection

There are many different techniques for detecting the distraction effects of in-vehicle technologies. The discussion below is restricted to a brief overview of the use of test track studies and driving simulators.

5.1.1 Test Track Studies

Test track studies seek to test distraction whilst drivers are in a "real world" environment. Participants are asked to drive a vehicle that has been equipped with one or more in-vehicle technologies. Drivers must negotiate a course whilst data concerning the effect of these technologies is collected by either an observer or data logger. This information is then compared against data collected from a vehicle that is not equipped with the technologies. Test track studies provide a safe environment to evaluate how distracting specific technologies are. However, in order to provide this specific information, other distractions are not provided in the scenario. For example, no other vehicle or pedestrians are usually present on the track. This is done to increase the safety of these tests and to remove potential distractions from distorting the findings. It has also been discovered that drivers' actions are influenced by the increased safety of the test track environment as they tend not to prioritise the driving task as highly as they would in an actual driving situation (Goodman et al., 1997; Rosencrance, 2004).

5.1.2 Driving Simulators

Driving simulators allow distraction to be tested without compromising the safety of the participants and allow the testing of distraction with multiple vehicle scenarios, which is not done with test-track studies. The use of simulators also allows greater control of the driving environment and offers the ability to change between many scenarios in a fraction of the time it would take to alter test track scenarios. However, driving simulators vary in quality and can provide a less than real experience. In addition, the cognitive resources required to perform tasks within a simulator may differ from those required in an actual driving situation (Goodman et al., 1997).

5.1.2 Distraction prediction

An alternative to measuring the distraction due to an in-vehicle device is to model distraction. This approach utilises a software system that enables the evaluation of new in-vehicle interfaces using cognitive models. This has face validity in that cognitive distraction is present when the driver is engaged in any activity that is not directly related to the primary task of driving, so that the inclusion of cognitive models in the evaluation program is highly desirable (Salvucci, Zuber, Beregovaia, & Markley, 2005). However, the relationship between predicting distraction and real world observations is not known.

6 Challenges for Context-Aware Systems

There is a great potential for distraction as a result of in-vehicle technologies and ADAS. These technologies increase the response time of the driver, thus giving them less time to react if a problem arises. Speech-based interfaces have been introduced in an attempt remove the visual and biomechanical distraction that was thought to impact on response times. However, there is evidence to suggest that the problem of cognitive distraction remains, effectively minimising any advantage that is gained when using these interfaces. Furthermore, as the variety of in-vehicle technologies continues to grow, there is an increased potential for multiple technologies to attempt simultaneous interaction with a driver. This means that there is a potential for the driver to be concentrating on a crucial manoeuvre when provided with information from multiple devices. This additional information is provided at the worst possible time, slowing the driver's reaction as their cognitive resources are used to interpret several simultaneous pieces of information. Context-aware systems could provide a solution to this problem; however several challenges exist for driver distraction research.

- What is the best method to enable in-vehicle technologies and ADAS to be context-aware?

The brief discussion above, on methods of detecting distraction due to in-vehicle devices shows that even this component of the context-awareness task presents challenges.

- How should the best moment for in-vehicle technologies or ADAS to interact with a driver be determined?

This is dependent not only on the on the intensity of information at the time, but also on driver state (e.g., stress). Methods for detecting and acting on driver state have not been discussed, but also present significant challenges.

- Should each device have a different way to interact with the driver?

Research into the modes which can be used as interfaces with in-vehicle technologies is underway, but little is known about how different modes are integrated by the driver

7. Conclusion

Driver distraction from in-vehicle technologies and Advanced Driving Assistance Systems is not a new issue. The distracting effects of various technologies and systems have been assessed using various means and have been found problematic. It is suggested that in addition to altering the way in which drivers interact with these technologies, the distracting effects should be minimised by restricting the ability of these devices to interact with a driver. The aim would be to minimise cognitive distraction. Context-aware systems offer the potential to achieve this by monitoring information flows from in-vehicle technologies and ADAS, the driving context and driver state. However, there remain significant challenges in operationalising a context aware system aimed at minimising distraction.

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References

Dey, A. K. (2001). Understanding and Using Context. *J. Personal and Ubiquitous Computing, 5*(1), 4-7.

Goodman, M., Bents, F., Tijerina, L., Wierwille, W., Lerner, N., & Benel, D. (1997). *An Investigation of the Safety Implications of Wireless Communications in Vehicles* (No. DOT HS 808-635): National Highway Traffic Safety Administration.

Harbluk, J. L., Noy, Y. I., & Eizenman, M. (2002). *The Impact of Cognitive Distraction on Driver Behaviour and Vehicle Control* (No. 13889 E): Transport Canada.

Huang, K. S., Trivedi, M. M., & Gandi, T. (2003). *Driver's View and Vehicle Surround Estimation using Omnidirectional Video Stream.* Paper presented at the IEEE Intelligent Vehicles Symposium, Columbus, OH, USA.

Janssen, W., Kaptein, N., & Claessens, M. (1999). *Behavior and safety when driving with in-vehicle devices that provide real-time traffic information*: TNO Human Factors Research institute.

Kanianthra, J. N. (2004). *Driver Distraction*. Retrieved Jan 25th, 2005, from http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/SAE/Convergence2004.pdf

Laberge-Nadeau, C., Maag, U., Bellavance, F., Lapierre, S. D., Desjardins, D., Messier, S., et al. (2003). Wireless telephones and the risk of road crashes. *Accident Analysis & Prevention, 35*(5), 649-660.

Lai, L., Cheng, K., Green, P., & Tsimhoni, O. (2001). *On the Road and on the Web? Compression of synthetic and human speech while driving.* Paper presented at the CHI'2001, New York.

Lansdown, T. C., Brook-Carter, N., & Kersloot, T. (2004). Distraction from multiple in-vehicle secondary tasks: vehicle performance and mental workload implications. *Ergonomics, 47*(1), 91-104.

Lee, J. D., Caven, B., Haake, S., & Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: The effect of speech-based e-mail on drivers' attention to the roadway. *Human Factors, 43*(4), 631-640.

Ranney, T. A., Mazzae, E., Garrott, R., & Goodman, M. J. (2000). *NHTSA Driver Distraction Research: Past, Present, and Future*. Retrieved March 15th 2005, from http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/PDF/233.PDF

Redelmeier, D. A., & Tibshirani, R. J. (1997). Association between cellular-telephone calls and motor vehicle collisions. *The New England Journal of Medicine, 336*(7), 453.

Rosencrance, L. (2004). *IBM, Honda delivering-car speech-recognition navigation system*. Retrieved 18th March, 2005, from http://www.computerworld.com/industrytopics/automotive/story/0,10801,95684,00.html

Salvucci, D., Zuber, M., Beregovaia, E., & Markley, D. (2005). *Distract-R: Rapid Prototyping and Evaluation of In-Vehicle Interfaces.* Paper presented at the ACM Conference on Human Factors in Computing Systems, Portland, Oregon, USA.

Stutts, J. C., Reinfurt, D. W., Staplin, L., & Rodgman, E. A. (2001). *The Role of Driver Distraction in Traffic Crashes*. Retrieved Feb 8th 2005, from http://www.aaafts.org/pdf/distraction.pdf

Transport Canada. (2003). *Strategies for Reducing Driver Distraction From In-Vehicle Telematics Devices: A Discussion Document* (No. TP 14133E): Transport Canada: Road Safety and Motor Vehicle Regulations Directorate.

Tsimhoni, O., & Green, P. (2001). *Visual Demand of Driving and the Execution of Display-Intensive, In-Vehicle Tasks.* Paper presented at the Human Factors and Ergonomics Society 45th Annual Meeting, Santa Monica, CA.

Utter, D. (2001). *Passenger vehicle driver cell phone use: results from the fall 2000 National Occupant Protection Use Survey*. Retrieved March 18th, 2005, from http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/RNotes/2001/809-293.pdf

Wierwille, W. (1993). Demands on driver resources associated with introducing advanced technology into the vehicle. *Transportation Research C, 1*(2), 133-142.

Young, K., Regan, M., & Hammer, M. (2003). *Driver Distraction: A Review of the Literature* (No. 206): Monash University Accident Research Centre.